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SECRET

25X1

[redacted]

November 2, 1970

Attention: John C.

Dear John:

Enclosed please find three (3) copies of Activity Summary No.18, [redacted]/2201201-AS-18.

25X1

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Sincerely,

[redacted]

Senior Staff Scientist

PSC/c
Enclosures

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WHEN SEPARATED FROM CLASSIFIED
ATTACHMENT

Declassification Review by NGA/DoD

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[redacted] Copy No. 2 of 2-e 25X1
No. of Pages 23 25X1

[redacted]

To: John C.

25X1 From: [redacted]

Subject: Quarterly Technical Report No. 2
Contract No. [redacted] 25X1

25X1 Reference: [redacted]2201201-QTR-2

This is the second quarterly technical progress report on
25X1 Contract No. [redacted] covering the program effort from 20 July 1970 to 19 October 1970. This report covers areas of program effort
25X1 conducted at the [redacted] facility and at the [redacted] 25X1
25X1 [redacted] on macro and micro optical image manipulation.

INTRODUCTION

During the past quarter a significant gain has been obtained in all areas of this program. The [redacted] 25X1 support program has been applied to evaluating partially coherent image manipulation methods for enhancing "low contrast" reconnaissance imagery. A series of imagery has been applied, including laboratory prepared resolution test targets during the initial phase and CORN target imagery during the second phase of image manipulation activity. This program is now at the threshold of evaluating the enhancement of continuous tone operational imagery.

25X1 The program at the [redacted] facilities is applied to microscope image processing methodology and to evaluation of macro image

GROUP 1
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manipulation for complex aberrations. The microscope processing methods provide a means to enhance high frequency imagery with one of the more important tools used for the extraction of image information. In this application we have applied a series of test targets with spatial frequencies up to 130 ℓ/mm. Viewing of the input target is being performed from 20X to 100X magnification, and "low contrast" image enhancement for the different scales is being evaluated. System parametric manipulation is being obtained in a manner that can be engineered into an operator controlled configuration, providing the operator with greater flexibility in controlling apparent image contrast.

Image manipulation of complex aberrations is also being performed at the [redacted] lab facility. This approach is being applied to three specific aberrations that are common to reconnaissance imagery. The first is a double imaging phenomena that occurs with defocusing of an annular aperture optical system. The second is a Besinc defocused function that occurs with a spherically symmetric optical system. The third is linear image blur. These aberrations require complex filters (both phase and amplitude components). Filters have been generated and applied to imagery prepared at the laboratory, and encouraging results are being obtained.

This report discusses these three areas of effort that are being simultaneously performed and cites results obtained. The direction to be taken during the next quarter is also outlined.

1. [redacted] Program

The status of this program, at commencement of the second quarter on 20 July 1970, consisted of completion of the initial laboratory development effort in holographic image manipulation and initiation of partially coherent image manipulation techniques with the in-line optical system. During the first weeks of this

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lab effort emphasis was placed on fabrication of low frequency attenuation filters and generation of laboratory prepared test targets. A number of filters, consisting of diameters from 1 to 8 mm and densities up to approximately 2.0D, were fabricated for test and evaluation. Images of a 1951 Air Force resolution test a target were fabricated for the initial test imagery.

Following initial efforts on the optical bench several improvements were effected to avoid coherent noise problems and to incorporate flexibility in controlling system response characteristics. It has been shown that the system frequency response can be described by the equation

$$F(w) = P(w) \circledast [P^*(w) \cdot S'(w)]$$

where $P(w)$ is the complex amplitude transmittance of the lens pupil function, $P^*(w)$ is its complex conjugate, and $S(w)$ is the source image function in the lens pupil plane. We control $S'(w)$ with a ground glass diffuser and collimator that provides continuous control of source diameter. $P(w)$ is affected with transmission filters that control both the attenuation level of information as well as the spatial frequency range to be attenuated. Series of filters have been produced and evaluated and optimized for bar targets, including the three bar Air Force test target and a CORN target. Data has been gained that demonstrates contrast enhancement and further resolution gain from the optical enhancement prodedure. Figure 1 illustrates contrast gain obtained by the optical process, where the input image contrast (evaluated as the ratio of I maximum to I minimum) and the processed image contrast are plotted as a function of bar group. Note that an additional bar group has been gained with the enhancement procedure.

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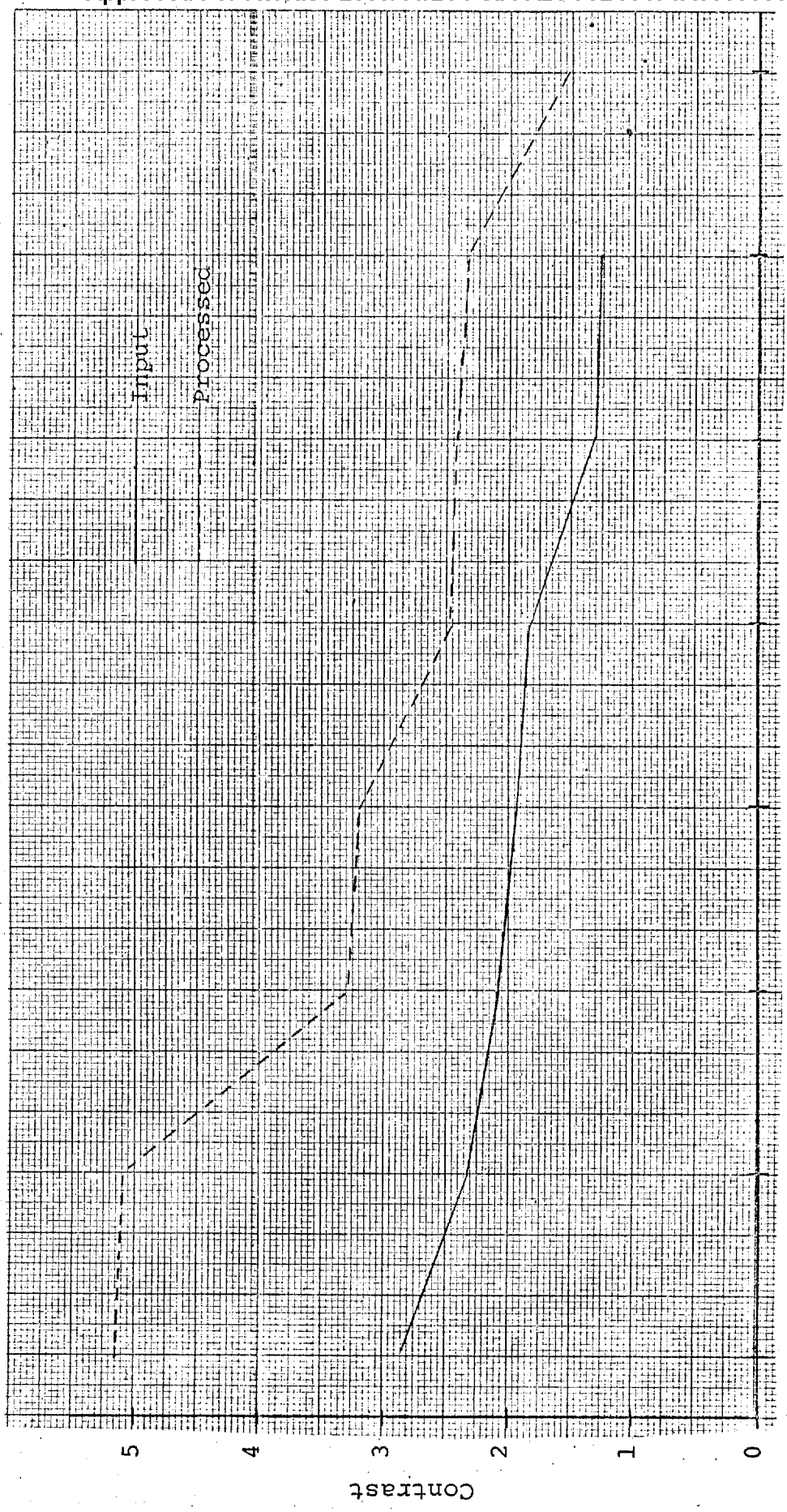

Figure 1. Comparison of the Contrast and Resolution Enhancement by Image Manipulation.

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During the coming period this program will be directed to processing of continuous tone imagery. This effort will require evaluation of system configuration and filters. Preliminary evaluation of the system has been performed and some modification effected to allow input of contact prints of material at high resolution rather than lower resolution enlargements. Evaluation of this imagery will be performed on the basis of information extraction capability after processing as compared to the input image. Further system evaluation will be performed by edge trace analysis or similar objective measurement criteria.

2. Microscope Image Manipulation

The microscope image manipulation program is similar in approach to the macro processing we are performing at the 25X1 facility except that the processing is being performed with a microscope with 2X, 4X and 10X objectives and a 10X eyepiece. The system is described by the diagram in Figure 2. The analysis as previously described is applicable to the microscope. A rotating ground glass element is used at the illuminating source to provide a time varying diffuse field and continuous source diameter control. "White" light from a mercury lamp has been used for illumination, demonstrating that the processing mechanism can be performed under such illumination conditions. Filter tolerances are more critical in the microscope because of the dimensional characteristics, namely the small focal length of the optics used. Low pass filters have been applied with the microscope showing a smoothing operation that can remove some of the granularity of imagery at high magnifications. Low frequency attenuation filters have also been applied, yielding enhanced results similar to that illustrated in Figure 1.

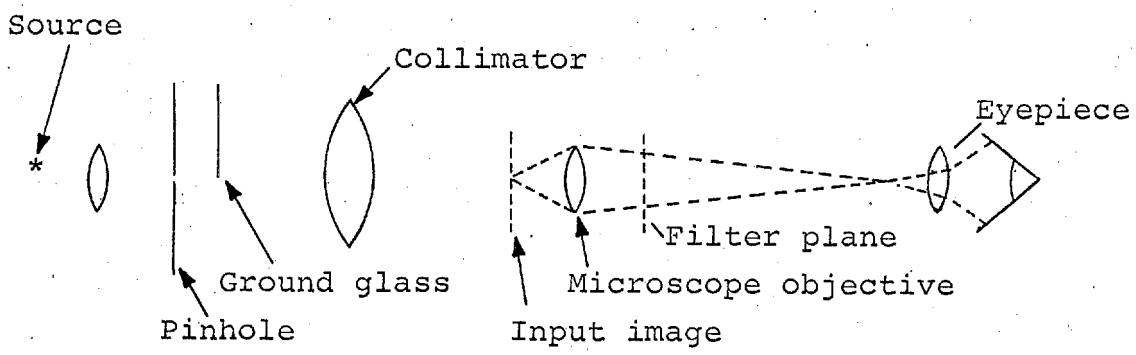

Figure 2. Microscope Processing System.

During the coming period we are evaluating filters especially for the 10X objective case where low noise is required and tolerances are most critical. Results of the microscope process will be evaluated and demonstrated with pictorial data. Application to continuous tone imagery will be included in this demonstration.

3. Macro-Image Manipulation

Macro image manipulation is also being performed using the coherent optical system illustrated in Figure 3. A mercury arc source is imaged onto a pinhole by a condenser lens and the light collimated by lens L_c.

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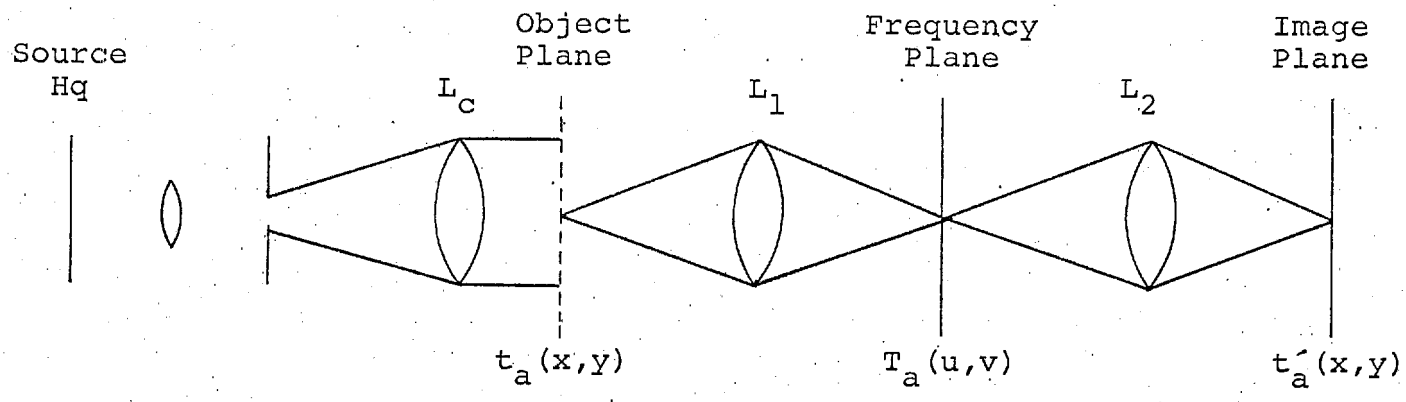

Figure 3. Image Manipulation System.

The Fourier Transform (Fraunhofer Diffraction Pattern) of the amplitude distribution $t(x,y)$ of a transparency placed in the collimated beam is effected by the lens L_1 and appears in the frequency plane as $T_a(u,v)$. It is in this plane that complex spatial filtering is performed by inserting filters with complex amplitude transmittance. The spectrum is then re-transformed by the lens L_2 and the restored image $t_a^1(x,y)$ appears in the image plane.

Since the coherent optical system is linear in amplitude the transparency must be manipulated such that its amplitude transmittance is proportional to the original intensity transmittance. This is accomplished by printing the original photograph so that the product of the original negative gamma and the positive print gamma are equal to 2.0, i.e. ($\gamma_n \gamma_p = 2.0$). When this condition is realized the amplitude spatial frequency distribution can be filtered using complex linear filters. In

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the course of this program appropriate sensitometry for SO380 and 2430 film was determined and used to produce input transparencies that obey the linearity condition. Transparencies with three typically encountered degradations, linear image motion, defocus and double imaging, were generated and enhanced with favorable results.

The most difficult part of optical image manipulation is encountered in the manufacture of the filters. Phase filters were generated for each of the degradations using a photographic bleaching technique and measured with a Mach-Zehnder interferometer. Amplitude filters were then constructed having constant transmission values between the zeros of the transfer functions describing the degrations. Although the combination of these amplitude and phase filters performed reasonably well - producing enhanced imagery - there was a large amount of coherent ringing due to the sharp discontinuties of the amplitude filters. This condition is presently being corrected by generating softer amplitude filters using other coherent optical techniques. Preliminary results of this experimentation have been quite promising. In attempting to improve system performance a fluid gate has been constructed and refractive index fluids pruchased so that the relief "image" associated with the input transparency can be more effectively eliminated. Experimentation with the "softer" amplitude filters and the immersion fluids is receiving most of the current attention of the macro image manipulation program.

During the coming month this effort will concentrate on gaining demonstrable results that describe system operating potential. Preliminary results have been gained and it is fully expected that final results will be available the first week of December.

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Subject

Filters + Targets have been fabricated for low contrast experimental series.

Targets) 1) Diff. Limited Res Target.

2) Air Force 1951 tri-bar target.

3) CORN target imagery.

Filters

1.6	mm	diameter
3.6	"	"
5.6	"	"
7.6	"	"
9.6	"	"

Density of Filters

btwn. 0.3 + 0.85 selected gp.
up to ~1.7 D

1st Target to study

Low contrast Air Force res. target
max. resolution Gp 4 #6
using diffuse incoh. illum.
microscope.

Exposure series Pan-X film
Roll #1 a GG closest to pinhole – 7 9/16" to coll. lens +
Filter 0.82 D, #2 dia.
Exp. series 9 sec to 1/8 sec.
b Same as 1 but with target in a liquid gate Toluene C_7H_8
Fisher Sci Cat No T-324

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+ This dist. from back of clamp to face of upright.

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Subject

Toluene C_7H_8
Boiling range 110.4° - 111.1°C
Residue after evaporation 0.001%

Visual results (@ 24X microscope mag.)
5 liquid gate Gp 4 #5 + #2 filter et al
2 " " Gp 4 #6 "

Placing filter #2 from plate 1.680 the contrast improves greatly (at least visually).

Roll 2 a) 1/4 sec to 1 min exp of this result.

b) no filter case (just clear glass at filter plane).

---

c) Using filter plate 0.820, #3 filter - with GG power. ~~6 1/16~~ 7 2/16"

Results of Roll 1

A definite improvement in noise reduction by liquid gating.

However non-gated res. is at gp. 4 #6 (barely) + liquid gated stops at 4 #3 in one direction + 4 #6 (barely) in other direction. Gp. 4 #1 of gated is softer than non-gated. To check focus

Results of Roll 2

a) Gp 4 #6 clearly visible, 5 #1 in one direction possibly resolved. Sharpest of all.

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(b) Very low contrast - soft edges — resolution cuts off at about Gp 4 #4

(c) Very low contrast — looks same as (b).

Conclusion is that the higher density filter enhanced contrast & resolution better than others. Note:- Gp 4 #6 28
5 #1 32

To test focus of system with filter 1.68D, #2, & GG at 79/16" position

Through focus run

Position of camera for above photos 32.82 cm.

Roll 3

a) Focus series taken at

1	32.52 cm	1 sec exp.
2	32.62	"
3	32.72	"
4	32.82	"
5	32.92	"
6	33.02	"
7	33.12	"

b) Using filter 1.68D #3, repeat of 1-7 exp series

Results 1. 32.82 cm was best focus.

UNCLASSIFIED 2. The case (b) with larger diameter produced as good results as (a) but less noise. Can see Group 5 #1 in one direction.

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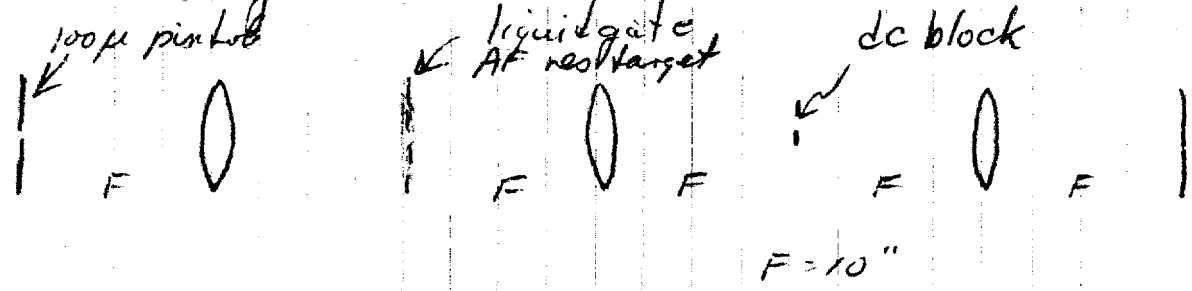
Subject 25X1

Roll 4

A good example of the d.c. blocking technique for edge enhancement. This is a limiting case.

System, no GG diffuser
Filter #1 from high density series about 1 mm dia. ; N.D. 2.0

System Diagram



Exposure Series 10 sec — 1/1000 sec.
(To be checked out on 9/24).

Results of Roll 4

A "differentiation effect" apparent but noise is prevalent. This demonstrates the extreme case by d.c. blocking — with image reversal.

Best result for this target obtained on 9/23 was in Roll #3 — where we obtained resolution of group 5 # 1 in one direction.

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Subject [redacted]

[redacted]

The through focus run was performed because when we compared the gated with non-gated imagery we found the gated to be "off" - and the result due either to defocusing when the gate was inserted in the system or to the fact that the phase relief image contributes to image information.

The through-focus run demonstrated that the gated image was in focus. Therefore it appears as if the phase component (phase relief image) contributes to image contrast. We will have to review this again before coming to a firm conclusion but the argument appears logical.

9/24/70

CRT Printer
- 16,000 × 16,000 address pts
- 4000 - 6000 separate diameter
- 0.5 - 1 mil spot size
- 0 → 64 gray levels (0.02)
- hysteresis on address spot position
- 5 - 720 K pts/sec
- 70 mm film

Computer 256 × 256 array

Check on ink-spray jet computer printout.

Program review with Hank C.

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Checkout of filters that were generated using Air Force target, liquid gated — GG at pos'n #1 (7 9/16")

Check-out with #2 filter spot dia. (3.6 mm)

		Filter	Req.		Comment
X	1	no filter	4-3	4-4	very low contrast
	2	0.36	4-5	4-5	improved "
	3	0.5	"		Same
X	4	0.6	4-6	4-5	4-6, H, has noise spot over it.
	5	0.68	4-6	4-6	
X	6	0.82	4-6	5-1	Gp 5 is starting to come in,
X	7	1.0*	"	"	"
X	8	1.15*	5-1	2	" (no improvement obvious)
X	9	1.62*	5-1	3	" Good contrast

Gp 5 appears more "distinct in latter input although light level is very low.

No inversion occurs upto this level.

We need to balance light levels to get better comparison & or record on film for comparison.

To test those noted by recording on film and comparing.

1	no filter	1/15 sec Hg.
2	0.36	1/8 "
4	0.6	1/4 "
6	0.82	1/2 "
7	1.0	1 "
8	1.15	1 1/2, 1 "
9	1.62	2 "

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a) un-numbered b) #11 (lower density) filter test 6) 1, 3, 10 " 2, 30 sec exp.

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Date Sept 24, 1958

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Subject

Results of exposures

Could see no noise apparent until the last two cases of high density filters.

1 4-3 - 4-4
2 4-4 - 4-3
4 4-4
6 11
7 4-4 - 4-5
8 4-5 (4-6 obscured by noise)
9 5-1 becoming apparent (noise disappearing)
a) 4-5 l.c.
b) 4-5 clear - noise superimposed on 4-6

* → 2

best case

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Student's Name

Tuesday Oct. 6, 1970

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Subject

To look into:-
statistics to determine sample required to obtain processed gamma to defined confidence limits, and samples required during production runs to maintain this confidence limits (quality control sample).

To do in the lab

1. quantify system response and relate to setbacks.
2. Apply system to CORN target imagery.
3. Apply to continuous tone imagery
4. Quantify system behavior for the above!

Objectives for next two months

---

1. John C. has traced the filters.

To quantify System Response #2 filters:

Nominal O	Actual O	Diameter @ D_{MAX} - 0.3
0.36	0.42	3.35 mm
0.6	0.65	3.3 "
0.82	0.91	3.25 "
1.0	1.01	3.2 "
1.15	1.18	3.15 "
1.62	1.99	3.35 "

Source at #1 pos'n. (1cm pinhole spin

1/4 sec dyp 3.5 mm

1 sec dyp 4 mm (@ 2cm sep'n)

1/4 sec dyp

1 sec dyp

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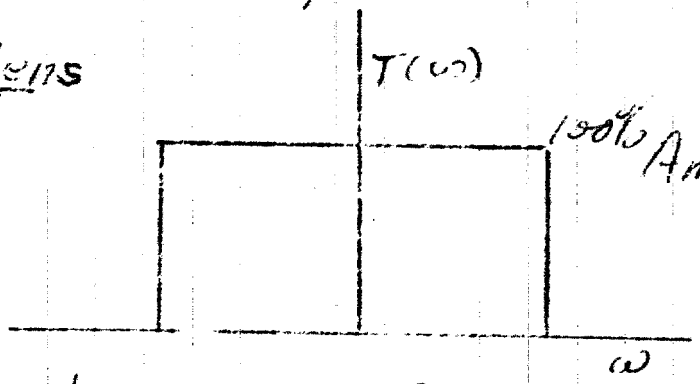
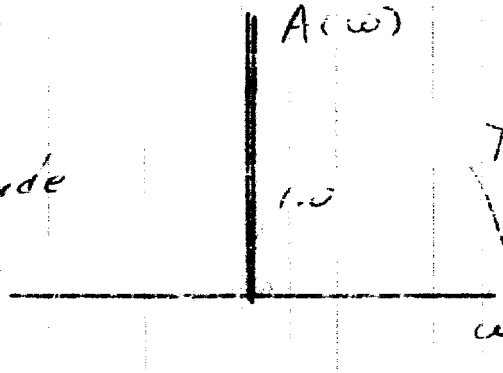
System pupil dia. is dia. of the 10" Faeger lenses — 2".

Pupil/lens



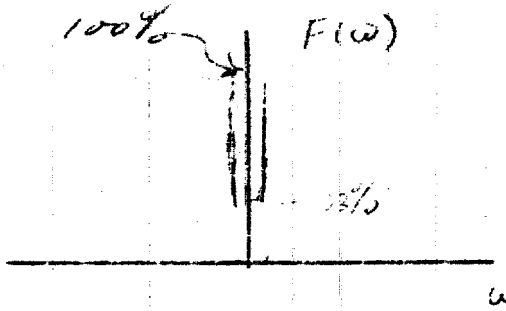
Source at #1 pos'n. (1 cm. btwn. pinhole & GG.)

Source distribution in pupil (filter) plane. 2.24" dia @ 1/2 dec dfp.



This is an estimate. Requires photometer scan to be defined. (Or accurate densitometry if scanned image on film.)

Filter distribution F(ω) 1.0 D, 3.2 mm dia. 3" dia @ 1/2



Amplitude transmittance

To plot response of system using above measured parameters.

Refer to Sec. 5 of Scott Lo.

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Report of best result of A.F. tri-bar resolution target.

Microscope view of original input

4 #'s resolved 5 #1 not resolved.
@ 30X Mag.

B&L ~~i3~~ - 30 X microscope
diffused white illumination

Using filter #2, 1.0 D } can visually see
1.15 D } 5 #1

GG at pos'n #1

Roll 1 To record on Pan-X film

Nominal D		Actual D
1.0D	¼, ½, 1 sec exposures	1.01 D
1.15D	½, 1, 2 " "	1.18 D
1.68D	1, 2, 4 " "	1.99 D

Results.

1.68 D Output is noisy at this density — resolution is off. (Reprocessed on some things else)

1.15 D Better than 1.0 ✗ but 4#6 not as good as original

1.0 D Best. 5#1 resolved.

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+ Note that this is better than previously on T.C. microscope (Reis Zoom) — see p 28

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CURN Target Images
2430 film contact print of ON

Visual resolution on 7-30 B+L microscope
a) in one direction 12-14 2-55-38 lines/mm
b) in other " 14

Visual resolution on optical bench
a) Op 15
b) Op 14 using 45X microscope objective

Roll 1 Test exposure series with filter #2, N.D. 1.01, 4 GG @ pos'n 1. best exp 1-4 sec.

Roll 2+ Filter #2

	exposure times	Resolution
0.91 D	1/2, 1, 2, 4 sec.	15/14
1.01	1/2, 1, 2, 4 sec.	see p 38
1.18	1, 2, 4, 8 "	for
1.99	4, 8, 16, 60 "	results

Roll 3+ Filter #3 approx. 6 mm. diameter

1.99 D		
1.18	same exp as above	see p 38 for
1.01	" Roll 2	RESULTS
0.91		

+ Note that we used Pan-X film input was on 2430.

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Results from C readings Zeiss

		(a)	(b)		
Roll 2					
	0.91 D	13	14	2 sec efp	
		15	15	4 "	(a) is continuous target.
	1.01 D	10-11	14	2 sec efp	(b) is three split in two.
	1.18 D	--- spurious ---			
	1.99 D	ringing — inversion poor image			
Roll 3	1.99 D	spurious — poor image ringing + inversion			
	1.18 D	ringing — poor image			
	1.01 D	ringing — 14 ' 14-15			
	0.91 D	12			

Roll 3 was inconclusive.
0.91 D of Roll 2 was best. Note also that system was initially set up for this one. Focus may change (as sometimes suspected from visual examination) with different plates.

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Subject

Because of the inconclusive results obtained on Rolls 2 & 3 a repeat & re-testing of the system is required.

a) It appears that factors might have caused some limitation to the results.

b) There is also a question as to the effect of different placement, namely do they input a spherical wavefront (or other form of alternating current)

that causes a shift —

System reviewed — output recorded on Rm-4 — repeat of Roll 2 of yesterday — Filter #2 (4mm)

Roll 1

Results — 2nd Best output at 1780 filter —

* → Ringing with 1990 filter — 1916 with two filters

From [illegible]

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Student's Name

Date 10/8/70

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Subject

Photographic results on this page.

Results from p. 28 Liquid gate comparison

p 32 High frequency + contrast enhancement with filter up to 1.99 D.

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Student's Name Date

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Subject Preliminary Image Processing Results from [redacted] Lab.

Instructor's Name

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Photo here

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